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Preliminary communication

The relationship between positive and negative automatic thought and activity in the prefrontal and temporal cortices: A multi-channel near-infrared spectroscopy (NIRS) study

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ABSTRACT

Background: Recently, neurobiological studies of the cognitive model of depression have become vastly more important, and a growing number of such studies are being reported. However, the relationship between the proportion of positive and negative automatic thought and activity in the prefrontal and temporal cortices has not yet been explored. We examined the relationship between brain activity and the proportion of positive and negative automatic thought in patients with major depressive disorder (MDD), using multi-channel near-infrared spectroscopy (NIRS).
Methods: We recruited 75 individuals with MDD (36 females; mean age $= 39.23 \pm 12.49$). They completed the Hamilton Rating Scale for Depression, Automatic Thoughts Questionnaire-Revised, Japanese version of the National Adult Reading Test, and the State-Trait Anxiety Inventory. Brain activation was measured by 52-channel NIRS.
Results: We found that activation in the vicinity of the right superior temporal gyrus is related to a deviation to negative of the proportion of positive and negative thoughts in individuals with MDD. Left dorsolateral prefrontal cortex activity was higher in the group with comparatively frequent positive thought.
Limitations: Our participants were patients taking antidepressant medication, which is known to influence brain activity. Second, the poor spatial resolution of NIRS increases the difficulty of identifying the measurement position.
Conclusions: We found that activation of the prefrontal and temporal cortices is related to the proportion of automatic thoughts in the cognitive model of depression.
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1. Introduction

Major depressive disorder (MDD) is one of the most common mental disorders, with a lifetime risk of approximately 9% for males and 17% for females (Hasin et al., 2005). MDD is diagnosed when a persistent and unreactive depressive mood and/or the absence of positive affect are accompanied by a range of symptoms, the number and combination of which needed to make a diagnosis are operationally defined (American Psychiatric Association, 2000). The effectiveness of treating MDD with cognitive behavioral therapy (CBT) has

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been substantiated by a growing number of clinical intervention studies (e.g., Cuijpers et al., 2008; Dobson, 1989). For example, CBT was found to significantly reduce depressive symptoms in a meta-analysis of randomized controlled trials (Beltman et al., 2010).

One possible factor in CBT's effectiveness in treating depression is that MDD is characterized by enhanced negative information processing (e.g., Beck, 1976; Teasdale, 1985). Depressive patients have frequent negative automatic thoughts about themselves, their future, and the world (Beck, 1967); these automatic thoughts induce depressive mood states in the cognitive model of depression. Hollon and Kendall (1980) found that patients with MDD showed significantly greater numbers of negative automatic thoughts than non-MDD patients. Therefore, for CBT to be effective in treating depressive symptoms, it is important that automatic thoughts become more functional and positive (e.g., Furlong and Oei, 2002).

Recently, the effects of negative and positive cognition in MDD have been investigated. Ingram and Wisnicki (1988) found an inverse relationship between the frequency of positive thoughts and the level of dysphoria. In addition, Kendall (1983) suggested that an examination of both the positive and negative dimensions of cognition might contribute to a greater understanding of the psychopathology of MDD.

The state of mind (SOM) model was proposed as a model incorporating both positive and negative dimensions (Schwartz and Garamoni, 1986). The primary focus of the SOM model is the proportion of positive and negative thoughts, although overall frequency of thoughts has potential significance as well (Schwartz and Garamoni, 1989). The SOM model suggests that adaptive psychological functioning is characterized by an optimal proportion of positive and negative cognition (Schwartz and Garamoni, 1986). This model posits five states of mind: positive dialog, internal dialog of conflict, negative dialog, positive monologue, and negative monologue. They are defined by the SOM ratio (the ratio of positive cognitions to sum of positive and negative cognitions: *Positive cognitions*/(*positive cognition+negative cognition*)). Positive dialog is the internal dialog between positive and negative cognition (defined by an SOM ratio of $.62 \pm .06$), hypothesized as optimal for coping with stress. The internal dialog of conflict, defined by an SOM ratio of $.50 \pm .06$, is associated with mild levels of psychopathology. Negative dialog (defined by an SOM ratio of $.38 \pm .06$) is associated with moderate psychopathology. Positive monologue consists of all positive cognition and is defined by an SOM ratio of .69 or more, while negative monologue (all negative cognition) is defined by an SOM ratio of .31 or less; this is an indicator of extreme psychopathology (Schwartz and Garamoni, 1986). SOM ratios of patients with major depression were found to be approximately .35, therefore qualifying as negative dialog (Garamoni et al., 1991; Schwartz et al., 2002).

Some neuroimaging studies have suggested a deterioration in cognitive function in MDD (Disner et al., 2011; Noda et al., 2012). Disner et al. (2011) showed that the neurobiological mechanisms that putatively underlie cognitive biases in depression seem to be influenced by neurobiological processes and a diminishing of the top-down system. According to Disner et al. (2011), the neurobiological process is best attributed to a bottom-up pathway that begins in the amygdala and proceeds through the subgenual and anterior cingulate cortex, striatum, nucleus accumbens, and hippocampus to the prefrontal cortex (PFC). In fact, the attenuation in cognitive control seems to be region-specific, for example, the dorsolateral prefrontal cortex (DLPFC) for rumination and cognitive bias and the ventral lateral prefrontal cortex (VLPFC) for biased attention; this curbs the top-down relationship with the pertinent subcortical regions (Disner et al., 2011). Thus, executive functions such as cognitive control are thought to be important in emotion regulation, including the regulation of negative automatic thoughts in MDD.

Many neuroimaging studies of MDD use the verbal fluency task (VFT) to examine executive function (Matsuo et al., 2002; Okada et al., 2003). The VFT is a simple task frequently used in neuroimaging studies that is known to activate the PFC in healthy subjects (Alvarez and Emory, 2006; Frith et al., 1991; Schlösser et al., 1998). Previous studies have suggested that patients with MDD have a reduced response in the left PFC during the VFT (Okada et al., 2003). In addition, the VFT is useful in evaluating semantic memory functions inspired by specific verbal stimuli (Sumiyoshi et al., 2005) and in examining the statements made during the task (McGurk and Meltzer, 2000). Thus, the VFT could be used as a cognitive task to examine the information processing of automatic thoughts triggered by external environmental stimuli.

The VFT is often used in near-infrared spectroscopy (NIRS) studies of MDD. NIRS is a non-invasive optical technique that monitors hemodynamic changes related to cortical neural activity by measuring the concentrations of oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb) in capillary blood vessels (Villringer and Dirnafl, 1995). Recent research suggested that reduced right frontal and temporal cortex activation visible by NIRS during the VFT is related to the severity of symptoms of MDD (Noda et al., 2012). Additionally, VFT can show significant differences between healthy controls and patients with MDD or bipolar disorder by the increases in oxy-Hb in the front-temporal regions (Kameyama et al., 2006; Matsuo et al., 2002; Pu et al., 2008; Suto et al., 2004). NIRS is frequently used with the VFT to examine the PFC (Suda et al., 2010). Because measurement via NIRS is conducted with the subject in a seated, natural posture, this is a low-invasive method that places few burdens on subjects. Therefore, NIRS is considered suitable for examining patients with psychiatric disorders such as MDD.

In the present study, given that cognitive function is important to emotion regulation in MDD, we hypothesized that a high SOM ratio (high positive automatic thought) in patients with MDD would activate the PFC, related to cognitive control, based on the findings of Disner et al. (2011). Thus, we examine the relationship between the ratio of positive and negative automatic thoughts and activity in the prefrontal and temporal cortices based on oxy-Hb changes as shown by multi-channel NIRS.

2. Methods

2.1. Participants

Seventy-five participants (36 females, 39 males; mean age$=39.23 \pm 12.49$) were recruited from among in- and out-patients receiving treatment for MDD at the National Center of Neurology and Psychiatry in Japan. Participants had been diagnosed with MDD by experienced psychiatrists following the Structured Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, Text Revision (SCID: First et al., 1996; American Psychiatric Association, 2000). Participants were excluded based on remission status as defined by a score of 7 points or less on the Hamilton Rating Scale for Depression (HAMD; Hamilton, 1960). All participants were right-handed (as measured by the Edinburgh Handedness Inventory, Oldfield, 1971) native Japanese speakers with no history of head injury. This study was approved by the ethics committee of the National Center Hospital of Neurology and Psychiatry, and research was conducted in accordance with the Helsinki Declaration (as revised, 1989). Written informed consent was obtained from all participants after a complete explanation of the study.

2.2. Assessment of clinical symptoms and automatic thought

After NIRS scanning, all participants completed an assessment and clinical evaluation that utilized the following structured interview and questionnaires.

2.2.1. Hamilton rating scale for depression (17-item version, HAMD)

The HAMD (Hamilton, 1960) was administered by experienced psychiatrists to assess the severity of participants' depressive symptoms. The HAMD separates the frequency of the depressive symptom from its intensity in most items, refines several problematic anchors, and integrates both a structured interview guide and consensus-derived conventions for all items.

2.2.2. Automatic thoughts questionnaire-revised (ATQ-R)

The ATQ-R (Kendall et al., 1989) measures the frequency of cognitive self-statements associated with depressed mood. The Japanese version of the ATQ-R (Kodama et al., 1994) includes 28 items on negative automatic thoughts (NAT) and 10 items on positive automatic thoughts (PAT). All items are scored on a 5-point Likert scale, with 1=*not at all* and 5=*all the time*. The validity and reliability of the Japanese version of the ATQ-R was demonstrated by Kodama et al. (1994).

2.2.3. The Japanese version of the national adult reading test (JART)

The National Adult Reading Test (NART, Nelson and Willison, 1991) was used to calculate an estimate of participants' verbal IQ. The Japanese version of the national adult reading test (JART) was developed by Matsuoka and Kim (2006). The JART is a widely accepted tool that has been found to have good reliability and validity (Matsuoka and Kim, 2006).

2.2.4. State-trait anxiety inventory (STAI)

The STAI (Spielberger, 1983) is a widely used self-report scale for the assessment of state and trait anxiety in research and clinical practice. The Japanese version of the STAI (Nakazato and Mizuguchi, 1982) includes 20 items on state anxiety (STAI-S) and 20 items on trait anxiety (STAI-T). All items are scored on a 4-point Likert scale, with 1=*not at all* and 4=*all the time*. Validity and reliability of the Japanese version of the STAI has been proven by Nakazato and Mizuguchi (1982).

2.3. NIRS Measurement

2.3.1. NIRS system

Brain activity was measured by near-infrared spectroscopy (NIRS). In this study, the NIRS measurements were performed using a 52-channel ETG-4000 Optical Topography System (Hitachi Medical Corporation, Tokyo, Japan). This machine uses two set wavelengths of near-infrared light (695 and 830 nm) to recognize form differences in the absorption spectrum, enabling the measurement of oxy-Hb and deoxy-Hb (Maki et al., 1995). The 17 emitter probes and 16 detector probes were plugged into a holder and arranged into a 3×11 array. The distance between the pair of emission and detector probes was 3.0 cm; the measuring area between each pair of detector probes was defined as a "channel" (ch).

Probes were placed on participants' frontal region. The lowest probes were positioned along the Fp1–Fp2 line in accordance with the international 10–20 system used in electroencephalography.

2.3.2. Activation task

Changes in hemoglobin concentration were measured during the VFT (Takizawa et al., 2008). The cognitive activation task was structured to include a 30-s pre-task period, a 60-s task period, and a 70-s post-task period. For the pre- and post-task baseline periods, participants were instructed to consecutively repeat five Japanese vowels (*a, i, u, e, o*) aloud. During the task periods, they were asked to generate as many Japanese words as possible that began with a designated syllable. The initial syllables were presented in counterbalanced order among the participants, with each syllable changing every 20 s (0–20 s:/to/,/na/,/a/; 20–40 s:/se/,/i/,/ki/; 40–60 s:/o/,/ta/,/ha/) during the 60-s task period. Participants' task performance was measured by the number of words generated during each 60-s task period.

2.3.3. Measurement parameters of NIRS data

The obtained data were analyzed using the integral mode. The pre-task baseline was established as the mean oxy-Hb level over the 10-s period immediately preceding the task period; the post-task baseline was defined as the mean over 5–50 s following the task period; the liner fitting between the pre- and the post-task baselines was applied to the data between the these two baseline measurements. We examined oxy-Hb in this study because the detection of oxy-Hb is generally reported to be the highest in sensitivity and reliability when using light (Tamura, 2002). Therefore, we calculated the average increase in oxy-Hb from baseline levels for each channel during the task period.

2.3.4. Measurement environment

Each participant was seated in a comfortable chair and instructed to remain still in order to prevent movement artifacts—specifically, no head movements, no strong biting, and no unnecessary eyebrow movement during the NIRS measurements. Data clearly containing motion artifacts, based on both our observations and the NIRS recording, were excluded from further analyses.

2.4. Statistical analysis

First, we calculated the proportion of positive and negative automatic thoughts according to the SOM model (Schwartz and Garamoni, 1986): *positive thought*/(*positive thought+negative thought*). For our analysis, we considered the difference in the number of items, the score per item was used about a positive and negative each; higher scores indicate a greater number of positive automatic thoughts (PAT). Participants were classified into two groups depending on whether they scored ≥.5 SD above or below the mean of the SOM ratio: the High Positive group ($n=28$) and Low Positive group ($n=23$). The middle group (SOM ratio$=.34\pm.11$; $n=24$) was excluded from our analysis.

We then conducted χ^2 tests for sex and age, and two-sample *t*-tests for education (year), verbal IQ, HAMD, and task performance to examine the differences in demographic data and clinical symptoms between the High Positive and Low Positive groups to identify factors affecting brain activity. We used paired *t*-tests to compare average change in oxy-Hb levels (task period – pre-task baseline period). We also compared the number of words generated during the VFT.

A one-way analysis of covariance (ANCOVA) was then performed, with participants' groups as the independent variable and the during-task oxy-Hb changes as the dependent variable; variables significantly different between groups were included as covariates. Finally, we performed a correlation analysis to investigate the relationship between brain activity on channels that differed significantly in the groups and the task performance and clinical index excluding depressive symptoms. All statistical analysis was performed using PASW for Windows (Release 18.0.3; SPSS Japan Inc., Tokyo, Japan).

3. Results

3.1. Participants' automatic thoughts and severity of depression

Mean scores and correlations of the NAT, PAT, SOM ratio, and HAMD in all participants are shown in Table 1. Mean scores of the SOM ratio across all subjects showed a value defined as *negative dialog*. We also observed a moderate negative correlation between SOM ratio and depression severity ($r=-.48$, $p<.001$).

3.2. Increased activation from the baseline

In all participants, the average of oxy-Hb changes significantly increased in 50 channels between the baseline (pre-task period) and the task period (ch2–4, ch7, ch8, ch11–52, $p<.05$; ch1, ch9, ch10, $p<.10$) (Fig. 1).

3.3. Group characteristics

Demographic data and ATQ-R, HAMD, and STAI scores for each group of participants are shown in Table 2. There were no significant differences in sex, years of education, and verbal IQ, but significant differences were found in HAMD scores between the two groups ($t(49)=3.87$, $p<.01$: unbiased Hedges' $g=-1.07$, 95% CI [−1.66 to .48].): the Low Positive group was significantly higher than the High Positive group. In addition, we found a significant difference in age ($t(49)=3.15$, $p<.01$: unbiased Hedges' $g=.87$, 95% CI [.27–1.45]), revealing that participants in the High Positive group were significantly older than those in the Low Positive group.

3.4. Task performance

The number of words generated during the VFT did not differ significantly between the High Positive and Low Positive groups, $t(49)=1.59$, $p=.12$: unbiased Hedges' $g=.44$, 95% CI [−.12–1.00].

3.5. Differences in NIRS data by the proportion of positive and negative automatic thoughts

As shown in Figs. 2–4, the average of oxy-Hb change in the High Positive group was smaller than that in the Low Positive group at

Table 1
Descriptive statistics and correlations of automatic thoughts, SOM ratio and depression severity ($n=75$).

		Mean	[95% CI]	*SD*	1	2	3	4	5
1	ATQ-R total	94.35	[93.03 95.68]	32.91	–	−.55**	.98**	−.90**	.45**
2	PAT	19.88	[19.31 20.44]	5.97		–	−.40**	.83**	−.39**
3	NAT	113.80	[112.51 115.08]	30.87			–	−.83**	.43**
4	SOM ratio	.34	[.26 .41]	.11				–	−.48**
5	HAMD	17.12	[15.97 18.27]	6.15					–

Note: ATQ-R = Automatic Thoughts Questionnaire-Revised; PAT = Positive automatic thought; NAT = Negative automatic thought; SOM ratio = PAT/(PAT+NAT); HAMD = GRID-Hamilton Depression Rating Scale.
** $p<.01$.

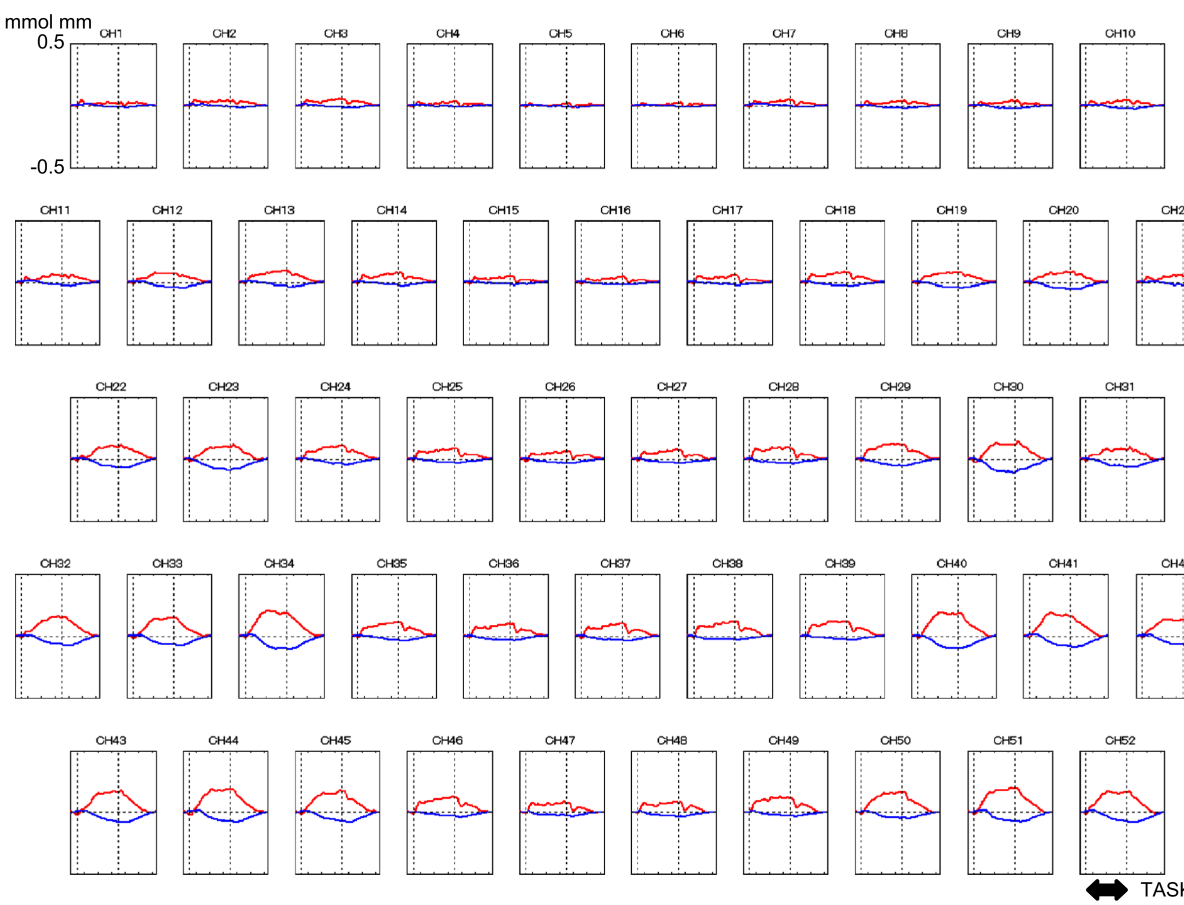

Fig. 1. The study sample ($N=51$) average of oxy-Hb (red line) and deoxy-Hb (blue line) during the 60-s Verbal Fluency Task (between the two dotted vertical lines in each graph) in 52 channels over the frontal and temporal regions as measured by NIRS. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 2
Characteristics of the participant's groups.

	High positive (n=23)		Low positive (n=28)		χ^2/t-Value	Unbiased Hedge's g [95% CI]
	Mean	SD	Mean	SD	df (49)	
Sex (M:F)	11:12		11:17		.38 *n.s.*	
Age	44.57	13.56	34.14	10.03	3.15**	.87 [.27 1.45]
Education (year)	14.13	2.65	13.96	1.95	.26 *n.s.*	.07 [−.48 .63]
Verbal IQ	103.46	11.66	102.93	9.91	.21 *n.s.*	.05 [−.50 .60]
HAMD	14.30	5.05	20.64	6.38	3.87**	−1.07 [−1.66 −.48]
Task performance	13.09	4.83	11.29	3.22	1.59 *n.s.*	.44 [−.12 1.00]

Note: HAMD=GRID-Hamilton Depression Rating Scale 17-item version; GAF=Global Assessment of functioning.
** $p<.01$.

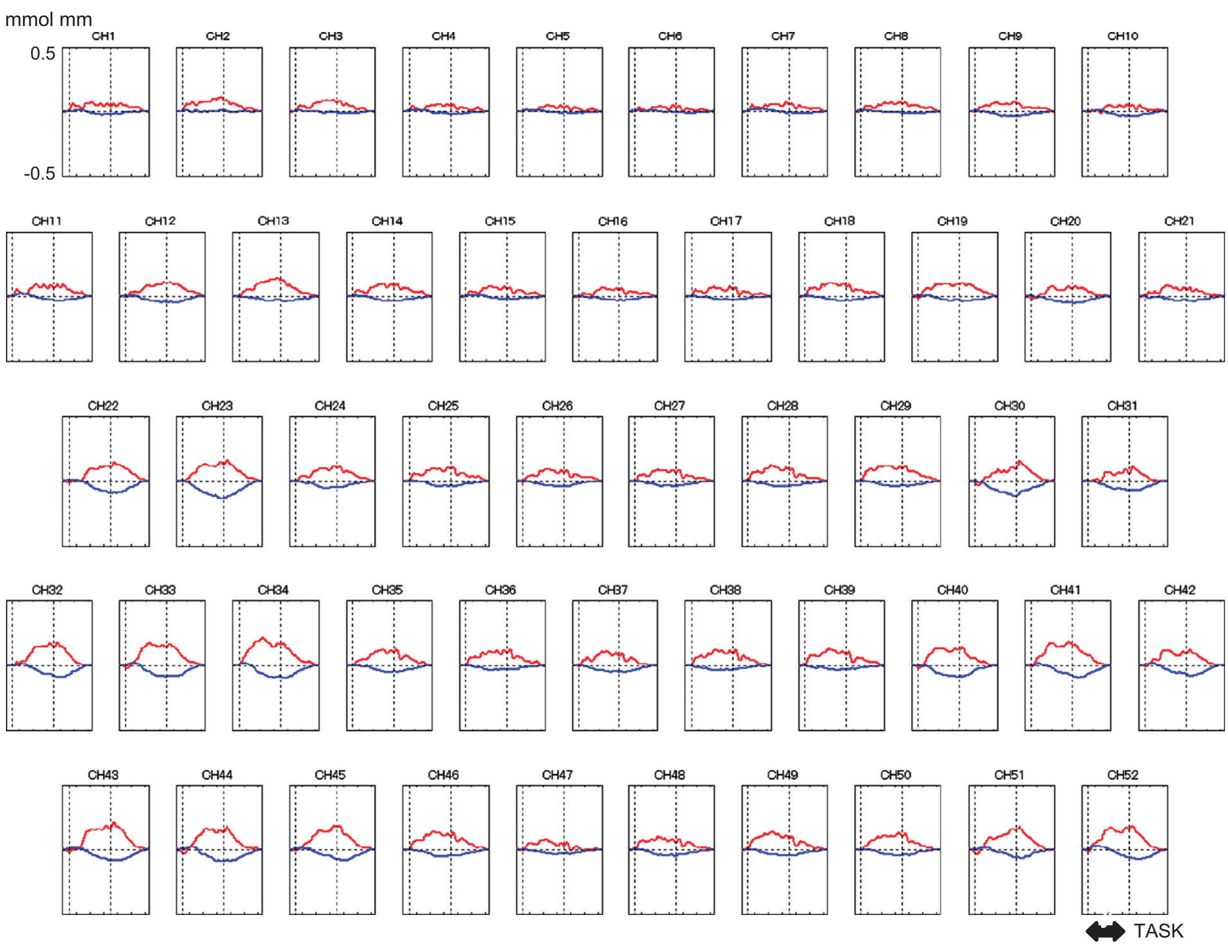

Fig. 2. The High Positive group (n=23) average of oxy-Hb (red line) and deoxy-Hb (blue line) during the 60-s Verbal Fluency Task. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

ch10 (F(1, 47)=2.98, $p<.10$: η^2=.060), ch11 (F(1, 47)=5.69, $p<.05$: η^2=.114), ch22 (F(1, 47)=4.09, $p<.05$: η^2=.091), and ch33 (F(1, 47)=3.28, $p<.10$: η^2=.072). In contrast, the average oxy-Hb change in the High Positive group was higher than that of the Low Positive group at ch28 (F(1, 47)=7.57, $p<.01$: η^2=.139). There were no significant differences among the other 48 channels.

3.6. Relationships Between brain activity in channels showing significant group differences, task performance, and clinical measurement

As shown in Tables 3 and 4, significant correlations were found between significantly different channels and the factors that may influence this difference. In the High Positive group, ch10, ch28, and ch33 showed significant positive and negative correlations with VFT performance (ch10: r=−.58, $p<.01$; ch28: r=.47, $p<.05$; ch33: r=.48, $p<.05$). However, in the Low Positive group, ch11 was significantly negatively correlated with STAI-S (r=−.49, $p<.05$).

4. Discussion

The purpose of this study was to examine differences in brain activity relevant to executive function according to the proportion of positive and negative automatic thoughts in patients with MDD, using NIRS. We classified participants into two groups based on

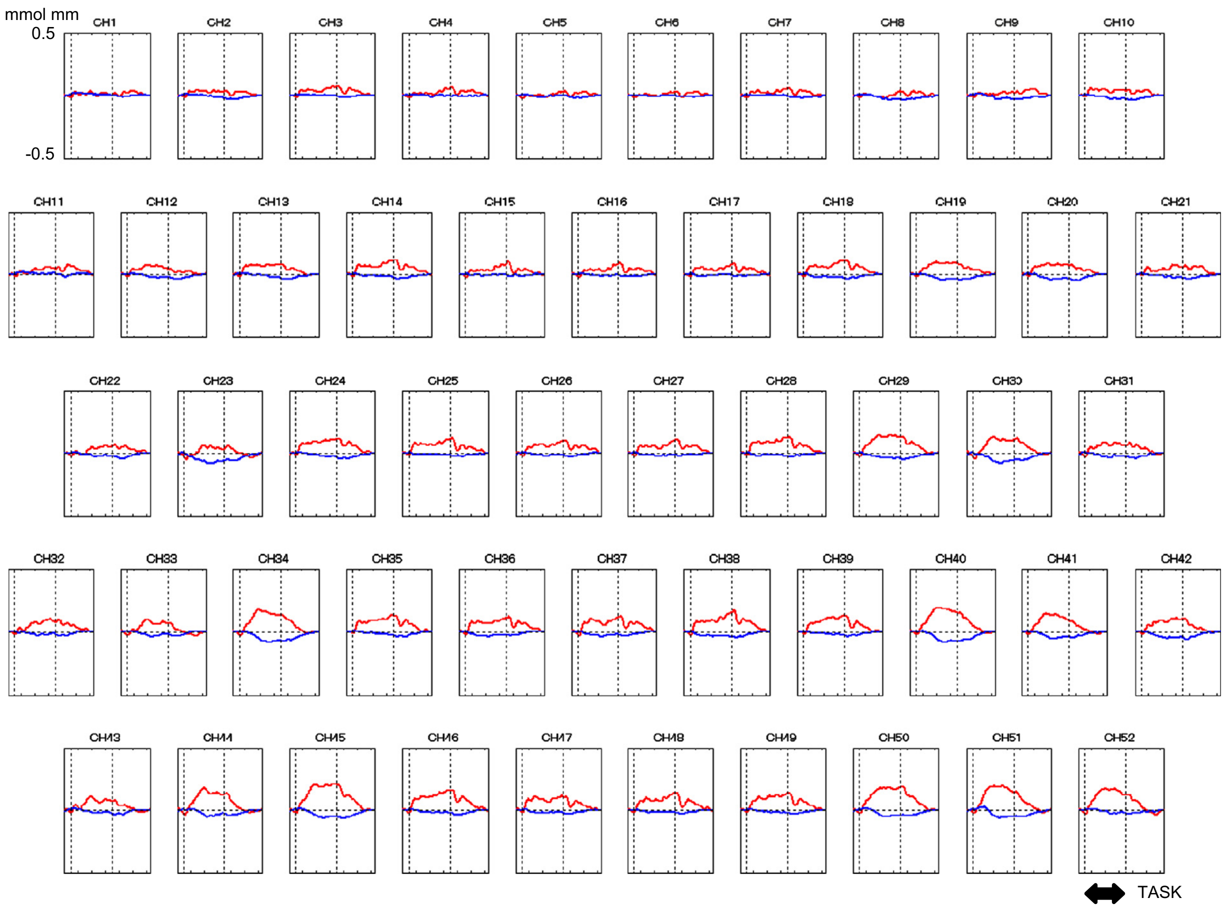

Fig. 3. The Low Positive group (n=28) average of oxy-Hb (red line) and deoxy-Hb (blue line) during the 60-s Verbal Fluency Task. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

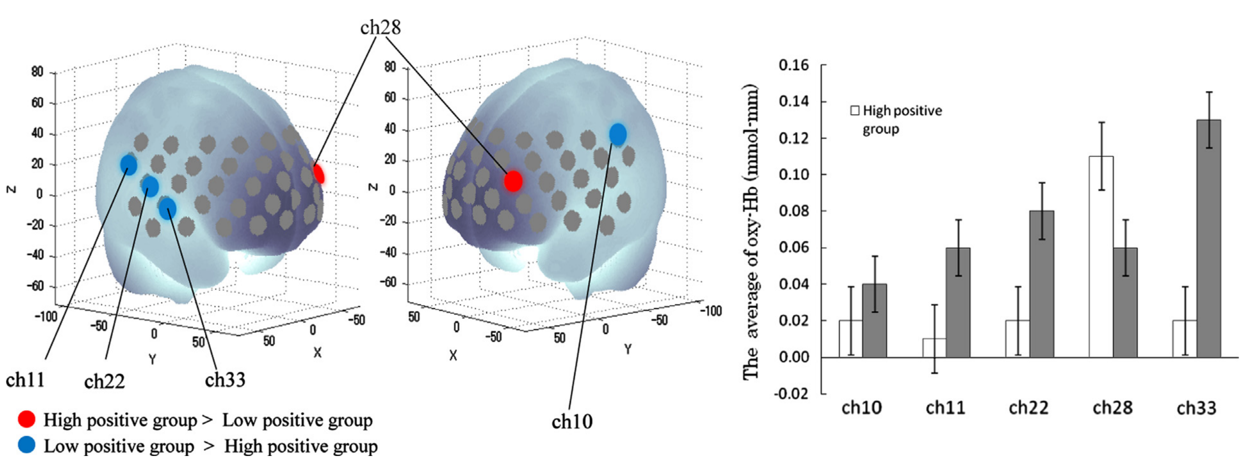

Fig. 4. Channels that differences were found in the average of [oxy-Hb] changes between the groups.

their proportion of positive and negative automatic thoughts, and then compared brain activation in each channel between the two groups. In this study, participants with a high frequency of positive automatic thoughts showed lower activation in the right superior temporal gyrus (STG) than did those with a low frequency of positive automatic thoughts, whereas participants with a high frequency of positive automatic thoughts showed higher activation in the left dorsolateral prefrontal cortex (DLPFC) than those with a low frequency of positive automatic thoughts.

We found that activation in the vicinity of the right superior temporal gyrus (STG; ch11, 33: by Tsuzuki et al., 2007) is related to a deviation to negative in the proportion of positive and negative automatic thoughts in MDD. The right STG is known to be associated with negative emotional processing. Our findings are consistent with those of a meta-analysis of functional neuroimaging studies in MDD patients that found increased right STG activity in MDD patients compared to healthy controls during the presence of a negative emotional stimulus (Fitzgerald et al., 2008). This suggests that hyperactivity in the right STG is associated not only with the negative emotion itself but also with the imbalance in the proportion of negative automatic thought to all automatic thought.

In our study, however, participants with a high frequency of positive automatic thoughts showed higher activity in the left

Table 3
Correlations between significantly different channels and STAI-S, STAI-T, and VFT performance in High positive group ($n=23$).

	ch10	ch11	ch22	ch28	ch33
STAI-S	.06	−.03	.14	.17	.29
STAI-T	−.03	−.16	.05	.25	.08
VFT performance	−.58**	.14	.40†	.47*	.48*

Note: STAI-S=State Anxiety Inventory; STAI-T=Trait Anxiety Inventory; GAF=Global Assessment of Functioning ; VFT=Verbal Fluency Task

** $p < .01$,
* $p < .05$,
† $p < .10$.

Table 4
Correlations between significantly different channels and STAI-S, STAI-T, and VFT performance in Low positive group ($n=28$).

	ch10	ch11	ch22	ch28	ch33
STAI-S	.05	−.49*	−.31	.08	−.15
STAI-T	.23	.08	.27	−.07	.19
VFT performance	.10	.36†	.11	−.14	−.08

Note: STAI-S=State Anxiety Inventory; STAI-T=Trait Anxiety Inventory; GAF=Global Assessment of Functioning ; VFT=Verbal Fluency Task.

* $p < .05$,
† $p < .10$.

DLPFC than did those with a low frequency of positive automatic thoughts. The DLPFC is involved in cognitive abilities characterized as executive functions (e.g., working memory and attention capacity) that help maintain goals and predict the future consequences of behavior. A large number of studies have shown impaired executive function and other functional abnormalities in the DLPFC of patients with MDD (Snyder, 2012); for example, Elliott et al. (1997) found decreased activation in the DLPFC in patients with MDD. In addition, Henry and Crawford (2005) showed that patients with MDD were significantly impaired on all verbal fluency measures, using the VFT as a multifaceted executive function task. Thus, impaired executive function in MDD patients is well established in the literature. According to Davidson (1995), the left hemisphere is dominant for processing positive/approach emotions. This study also showed that individuals who experienced more positive than negative thought showed more activation in the left DLPFC. It has further been reported that hypoactivity in the left DLPFC is associated with rumination (Ray et al., 2005); it is reasonable to propose that individuals who experience more negative than positive automatic thought may be more likely to ruminate (Wells, 2008). Hypoactivity in the DLPFC is correlated with altered patterns of rostral anterior cingulate cortex (ACC) activity, which is thought to contribute to rumination by facilitating the inhibition of positive information and impeding the inhibition of negative information (Elliott et al., 2002). The presence of either decreased inhibition for negative emotion or increased inhibition for positive emotion predicts greater severity of depressive symptoms (Eugene et al., 2010). Together, these findings support ours regarding variations in activity in the left DLPFC as we observed between participant groups in this study.

Our study revealed the relationship between automatic thoughts and prefrontal and temporal cortex activity in MDD. Porto et al. (2009) hypothesized that CBT can improve the brain functionally. Specifically, if individuals' depressive symptoms are improved after CBT, their automatic thoughts will become more functional (Maag and Swearer, 2005; Matsunaga et al., 2010). Moreover, we can prove this functional improvement with NIRS: the averages of oxy-Hb in ch10, ch11, ch22, ch28, and ch33 show the change in the proportion of automatic thoughts. In the future, we will be able to verify the effectiveness of CBT with NIRS; this possibility has been anticipated in recent studies (Mayberg et al., 2005).

Nevertheless, the current study has a few limitations. First, the sample comprised patients with MDD under medical treatment; most patients were taking medication at the time of measurement. Factors such as antidepressant medication and the duration of the disorder can affect brain activity, thereby confounding our results. Second, NIRS has poor spatial resolution, which complicates the identification of the measurement position when using NIRS alone. We compensated for this by positioning a probe as demonstrated in previous studies (e.g., Kameyama et al., 2004), but cannot discount this fundamental limitation of the method. We expect that the development of new measurement technology will eliminate this issue in the future.

In this study, we revealed that activity in the prefrontal and temporal cortices is related to the proportion of automatic thoughts in the cognitive model of depression. Our findings suggest the possibility of considering the dysfunction of a top-down system to a cerebral emotions region as a biological base of the cognitive model of depression. Findings such as these can contribute to promote a more accurate understanding of depression.

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Conflict of interest

All the authors declare that they have no conflicts of interest with respect to this study or its publication.

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